CALIFORNIA DIVISION OF MINES AND GEOLOGY

Fault Evaluation Report FER-69

January 19, 1978

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ILLUSTRATIONS

CALIFORNIA DIVISION OF MINES AND GEOLOGY

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1. Name of fault group

Faults along the San Gabriel Range front between San Antonio
Canyon on the east and Big Tujunga Canyon on the west. Includes such named
faults as the Sierra Madre fault, the San Antonio fault, the Sawpit
Canyon fault, the south branch of the San Gabriel fault, the JPL fault,
and the Mt. Lukens thrust fault.

2. Location of faults

This area lies mostly in Los Angeles County; only the extreme
eastern end is within San Bernardino County. The area includes parts
of each of the following U.S. Geological Survey 7½' topographic
quadrangles: Ontario, San Dimas, Mt. Baldy, Glendora, Azusa, Mt. Wilson,
Pasadena, Burbank, Condor Peak, and Sunland. See Figure 1 for location.

3. Reason for evaluation

These faults are located within the 1977 study area of the 10-
year program for fault evaluation.

4. List of references

Baird, A.K., 1956, Geology of a portion of San Antonio Canyon, San
   Gabriel Mountains. Unpublished M.A. thesis, Claremont College,
   Claremont, California, 91 p., 8 plates. Map scale 1:12,000.

Beck, A.C., 1968, Gravity faulting as a mechanism of topographic

adjustment: New Zealand Journal of Geology and Geophysics,

v. 11, no. 1, p. 191-199.

(Faulting similar to what he describes occurs on Mt. Lukens,

Pasadena quadrangle.)

California Division of Mines and Geology, 1976, Special Studies Zones

Map, Sunland Quadrangle. Scale 1:24,000.

California Division of Mines and Geology, 1977, Special Studies

Zones Map, Mt. Wilson Quadrangle. Scale 1:24,000.

Dibblee, T.W., Jr., 1958, Geologic map of the Pomona 15' quadrangle,

Los Angeles County, California. Unpublished map. Scale 1:62,500.

Dibblee, T.W., Jr., 1963, Geologic map of the San Antonio, Hesperia,

Ontario, and San Bernardino 15' quadrangles. Unpublished map.

Scale 1:62,500.

Dibblee, T.W., Jr., 1968, Geologic map of the Condor Peak 7½' quad-

rangle: U.S. Geological Survey Open File Report. Scale 1:24,000.

(Dibblee mapped only part of the south branch of the San

Gabriel fualt in this quadrangle, so his mapping is not used

in this report. Of the parts of the fault that he did map,

his locations are much more similar to those of Smith, 1977b,

than to those of Ehlig, 1967.)

Eckis, Rollin, 1934, South coastal basin investigation, geology and

ground water storage capacity of valley fill: California Division

of Water Resources Bulletin 45, 279 p. Map scale 1:150,000.

(This is one of the earlier maps to show faulting along

the range front; of no specific value to this report.)

Ehlig, P.L., 1967, Geologic map of a part of the central San Gabriel
    Mountains, California. Unpublished faculty research, California
    State College at Los Angeles. Scale 1:250,000.

>   (This map was the source for the locations of the north
>   and south branches of the San Gabriel fault in the Condor
>   Peak quadrangle, as used in compiling the Los Angeles Sheet,
>   Geologic Map of California.)

Envicom Corporation, 1975, Public safety and seismic safety elements
    technical report, cities of Alhambra, Arcadia, Duarte, El Monte,
    Monrovia, Monterey Park, Pasadena, San Gabriel, San Marino, Sierra
    Madre, South Pasadena, and Temple City. Unpublished report by
    Envicom Corporation, 129 p., 2 appendices, 2 plates. Map scale 1:24,000.

>   (Some of their fault mapping was used in the compilation of
>   figures 3a and 3b of this FER. They give no references,
>   however, as to the sources of their data on the location of
>   the faults.)

Jennings, C.W., 1975, Fault map of California with locations of
    volcanies, thermal springs and thermal wells: California Division
    of Mines and Geology, California Geologic Data Map Series, Map no. 1.
    Scale 1:750,000.

Kew, W.S.W., 1924, Geology and oil resources of a part of Los Angeles
    and Ventura Counties, California: U.S. Geological Survey, Bulletin
    753, 202 pages. Map scale 1:62,500.

>   (It appears that he was the first to use the name "Sierra
>   Madre fault" in print.)

Lamar, D.L., Merifield, P.M., and Proctor, R.J., 1973, Earthquake
recurrence intervals on major faults in southern California, In
Moran, D.E., Slosson, J.E., Stone, R.O., and Yelverton, C.A., eds.,
Geology, seismicity, and environmental impact: Association of
Engineering Geologists Special Publication, p. 265-276. Map
scale about 1:1,250,000.

    (They make a questionable calculation of earthquake recurrence
intervals along the Sierra Madre fault zone. They assume
that 370 feet of alluvium was deposited in only the last
10,000 or 20,000 years!)

Miller, W.J., 1928, Geomorphology of the southwestern San Gabriel
Mountains of California: University of California Publications,
Bulletin of the Department of Geological Sciences, v. 17, no. 6,
p. 193-240. Map scale 1:275,000.

    (This contains some of the earliest descriptions of
faulting along that part of the range front that is included
in this FER.)

Miller, W.J., 1934, Geology of the western San Gabriel Mountains of
California: Publications of the University of California at
Los Angeles in Mathematical and Physical Sciences, v. 1, no. 1,
114 p. Map scale 1:82,000.

Morton, D.M., 1973, Geology of parts of the Azusa and Mount Wilson
quadrangles, San Gabriel Mountains, Los Angeles County, California:
California Division of Mines and Geology Special Report 105,
21 pages. Map scale 1:12,000.

Payne, C.M., and Proctor, R.J., 1977, Geologic map of the Sierra
Madre fault zone between San Gabriel Canyon and Big Tujunga
Canyon, Los Angeles County, California. Unpublished map, work
in progress, California Institute of Technology, Pasadena,
California. Scale 1:12,000.

> (A reconnaissance map, but it provides the best available
> mapping of the range front between the northwestern corner of
> the Pasadena quadrangle and Big Tujunga Wash. Saxon copies
> of that part of their map are in the A-P room.)

Payne, C.M., and Wilson, K.L., 1973, The Sierra Madre fault system, in
Nicks, R.R., editor, Association of Engineering Geologists Field
Trips Guidebook, 1973 Annual Meeting, 11 p.

Proctor, R.J., 1972, Evidence for, and engineering consequences of
recent activity along the Sierra Madre fault zone, southern
California: Geological Society of America Abstracts with Programs,
v. 4, no. 3, p. 220-221.

Proctor, R.J., and Kalin, D.C., 1965, Geologic map and section along
the 6.2-mile Glendora tunnel: Unpublished map, The Metropolitan
Water District of Southern California. Map scale 1:12,000
(available in A-P files).

Proctor, R.J., Payne, C.M., and Kalin, D.C., 1970, Crossing the
Sierra Madre fault zone in the Glendora tunnel, San Gabriel
Mountains, California: Engineering Geology (Elsivier), v. 4,
no. 1, p. 5-63. Map scale 1:12,000.

Radbruch-Hall, D.H., Varnes, D.J., and Colton, R.B., 1977, Gravitational spreading of steep-sided ridges ("Sackung") in Colorado: Journal of Research of the U.S. Geological Survey, v. 5, no. 3, p. 359-363.

Real, C.R., Parke, D.L., and Toppozada, T.R., 1977, Magnetic tape catalog of California earthquakes, 1900-1974: California Division of Mines and Geology.

Saul, R.B., 1976, Geology of the west central part of the Mt. Wilson 7½' quadrangle, San Gabriel Mountains, Los Angeles County, California: California Division of Mines and Geology Map Sheet 28. Map scale 1:12,000.

Shelton, J.S., 1947, The Miocene Glendora volcanics in eastern Los Angeles County, California. Unpublished Ph.D. thesis, Yale University, New Haven, Connecticut, 121 p., 2 plates. Map scale 1:24,000.

Shelton, J.S., 1955, Glendora volcanic rocks, Los Angeles basin, California: Geological Society of America Bulletin, v. 66, no. 1, p. 45-90. Map scale 1:24,000.

Smith, D.P., 1977a, Geologic map of the north half of the Pasadena 7½' quadrangle, Los Angeles County, California. Unpublished map, California Division of Mines and Geology. Scale 1:12,000.

(There is a copy of this map in the A-P room.)

Smith, D.P., 1977b, Reconnaissance geologic map of the north and south branches of the San Gabriel fault, Condor Peak quadrangle, Los Angeles County, California. Unpublished map, California Division of Mines and Geology. Scale 1:24,000.

(There is a copy of this map in the A-P room.)

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Streitz, Robert, 1964, Preliminary geologic map of the SW¼ Glendora

quadrangle, Los Angeles County, California: California Division

of Mines and Geology Open File Report. Scale 1:9,600.

(He mapped only the faults that were actually exposed,

and did no inferring, interpolation, or extrapolation.

This statement also applies to the two maps listed

immediately below.)

Streitz, Robert, 1966, Preliminary geologic map of the SE¼ Glendora

quadrangle, Los Angeles County, California: California Division

of Mines and Geology Open File Report. Scale 1:9,600.

Streitz, Robert, 1967, Preliminary geologic map of the SW¼ Mt. Baldy

quadrangle, Los Angeles County, California: California Division

of Mines and Geology Open File Report. Scale 1:9,600.

Wallace, R.E., 1977, Profiles and ages of young fault scarps, north-

central Nevada: Geological Society of America Bulletin, v. 88,

p. 1267-1281.

Aerial Photography

Fairchild, 1931

Type: vertical, stereo, black and white

Scale: 1:4800

Date flown: 2/25/31

Coverage: Parts of the San Gabriel Range front in

La Crescenta, and part of the southwestern side

of Verdugo Mountain, Glendale.

Availability: Fairchild aerial photography collection,

Geology Department, Whittier College, Whittier, CA.

Fairchild, 1933

Type: vertical, stereo, black and white

Scale: 1:19,200

Date flown: December 1933

Coverage: Parts of the Pasadena, Condor Peak, Sunland, and

Burbank quadrangles.

Availability: Fairchild aerial photography collection,

Geology Department, Whittier, California.

5. Summary of available data

Because of the size and complexity of this fault system, It will be discussed in 5 parts:

A. The frontal fault zone, eastern part (Sierra Madre fault), between San Antonio Canyon and Monrovia Canyon, within the Mt. Baldy, Glendora, and Azusa quadrangles.

B. The Sawpit Canyon fault zone, within the Azusa and Glendora quadrangles.

C. The frontal fault zone, central part (Sierra Madre fault), between Santa Anita Canyon and Las Flores Canyon, within the Mt. Wilson quadrangle.

D. The south branch of the San Gabriel fault, within the Pasadena and Condor Peak quadrangles.

E. The frontal fault zone, western part (JPL and Mt. Lukens thrust faults), between Las Flores Canyon and Big Tujunga Canyons, within the Pasadena, Condor Peak, Burbank, and Sunland quadrangles.

A. Frontal fault zone, eastern part (Sierra Madre fault)

This fault zone Is difficult to define.

Figures 3a, 3b, and 3c are compilations of mapping in this area by Shelton (1947 and 1955), Dibblee (1958 and 1963), Streitz (1964, 1966, and 1967), Proctor and Kalin (1965), Proctor and others (1970), Morton (1973), and Envicom Corporation (1975). There is considerable disparity among these workers as to the location of the main faults. Most of the mapped faults cut bedrock in the lower part of the range front. Some faults are inferred beneath the alluvium just beyond the base of the frontal hills. Shelton (1947 and 1955) and Proctor and

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Kalin (1965) infer faults farther out beneath the alluvium on the basis
of apparent ground water barriers. Shelton (1947) obtained his water-
well data from unpublished sources and made his own interpretations.
Proctor and Kalin (1965) refer to their inferred fault across the Dalton
fan as "L.A. County Flood Control District groundwater barrier." The
occurrences of outlying hills to the south of the range front, such as
the South Hills and Way Hill on figure 3b, imply additional subsurface
faults that have not yet been located. Proctor and others (1970) encoun-
tered what appear to be major fault zones within the Glendora tunnel.
The tunnel location and the compilation of their mapped surface faults are shown
on figures 3b and 3c.

At its western end, this portion of the frontal fault zone
converges with the southwestern end of the Sawpit Canyon fault zone.
The Raymond Hill fault trends toward this point from the west-southwest.
At the eastern end, the frontal fault zone presumably splits. One branch
extends up San Antonio Canyon to the north-northeast, and is known as
the San Antonio fault (Baird, 1956). Presumably, another branch of the
frontal fault zone also continues eastward along the range front where
it is known as the Cucamonga fault.

The scattered fault plane attitudes available for this area
show the faults to be generally north dipping. Morton (1973, p. 16)
states that along the range front to the east of Santa Anita Canyon
the faults are mostly northward-dipping reverse faults. He states (p. 19)
that the total uplift of the San Gabriel Mountain front relative to the
bedrock floor of the San Gabriel Valley in this area is on the order
of 10,000 feet. This uplift started as far back as middle Miocene time,

however. The Pleistocene uplift may be considerably less than half of that value.

The Glendora tunnel, constructed in 1966, provided another view of the range front fault system. Proctor and Kalin (1965) and Proctor and others (1970) documented the geologic features along the tunnel and in nearby exploratory drill holes. They encountered one major thrust fault zone (diagrammed in figure 3 of Proctor and others, 1970), and several other high-angle faults. The thrust fault, which dips about 12° northward, was encountered near Sycamore Canyon (near the eastern portal of the tunnel). They show this fault, on their tunnel profile, to not extend to the ground surface. This fault is apparently the same as the dashed and dotted fault, shown on their surface geologic map, that lies about 900 feet north of the eastern portal of the tunnel. In the tunnel profile, they show Miocene Puente Formation, along with fault slivers of gneiss and granite, thrust over Pleistocene alluvial deposits along this fault. Proctor and others (1970, figure 4) refer to this feature as the "Buried trace of the Cucamonga fault," an assumption for which they provide no supporting evidence. Other workers, however, raise the question as to whether this thrust fault is instead the basal slide plane of a major landslide. Shelton, for example (1955), maps the entire lower part of the range front between San Dimas Wash and Big Dalton Wash as a "Zone of faulting and sliding." He states (p. 78), "the belt labeled "Zone of faulting and sliding" (plate 1) is one in which the few discontinuous contacts that can be followed do not make structural sense, on the scale of present mapping, except as part of such a zone." Robert Streitz (personal communication, 12-20-77) believes it probable that the entire

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area between San Dimas Wash and Big Dalton Wash may be one massive, ancient landslide, and that the 12° thrust fault near the eastern portal of the Glendora tunnel may in fact be the base of the toe of the slide. Proctor and others (1970, p. 59) consider this possibility, but rejected it. However, their cross section (their figure 3) of the thrust fault shows younger rock (upper Miocene Puente Formation) thrust over older rock (middle Miocene Topanga Formation). This is out of character. To the writer's knowledge, all other reverse or thrust faults along the San Gabriel Mountain front are in character -- that is, the upper plate is either the same age or older than the lower plate.

The upshot of this discussion of the Glendora tunnel is that the geologic data taken from that project are not sufficient to conclusively define the "Sierra Madre fault zone" in that area.

None of the workers except Shelton (1955) give evidence for fault movement along this part of the range front. Shelton shows a fault north of Azusa cutting Holocene alluvium. He gives no discussion of this in his text; it may be a drafting error. Shelton also shows an east-west-trending fault cutting late Pleistocene alluvium just north of San Dimas. This fault should have been encountered in the Glendora tunnel near the eastern portal, but the tunnel profile of Proctor and others (1970) shows no faults in that area. Baird (1956, p. 69) says that the last movement on the San Antonio fault zone is older than the undisturbed higher terrace (Qt_3) that overlies the fault. D.M. Morton (personal communication, 10-7-77) says he knows of no geologic features indicative of Holocene faulting along the range front between San Antonio Canyon on the east and Eaton Wash on the west. R. Streitz (personal communication, 12-20-77)

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says that he knows of no such features in the part of the range front

area that he mapped -- that is, from San Antonio Canyon on the east to

the western boundary of the Glendora quadrangle. Proctor and others

(1970, p. 57) give the following quote:

> According to R.H. Jahns (personal communication, 1965)
> "The Glendora tunnel would extend across the Sierra Madre fault
> zone, but relatively low known seismicity in this area, fortified
> by geologic evidence indicating little or no fault displacement
> for thousands of years before present (based on locally undisturbed
> terrace gravels at least 10,000 years old), leads to the conclusion
> that possibilities for serious earthquake damage during the useful
> life of the structure are fairly remote."

Later, however, Proctor, in conjunction with Lamar and Merifield

(Lamar and others, 1973, p. 273), makes the following argument for an

earthquake recurrence interval along this part of the range front of

212 years or less:

> Evidence for recurrence of earthquakes in this area was
> provided by the excavation of the Glendora Tunnel in 1966
> (Proctor, Payne and Kalin, 1970). At a depth of 370 feet below
> the ground surface and 700 feet north of the surface trace of the
> Sierra-Madre-Cucamonga fault, geologists of the Metropolitan
> Water District found Miocene shale, containing fault slivers of
> gneiss and granite, thrust at least 700 feet over Quaternary
> terrace deposits. If it is assumed each uplift pulse was 150 cm
> (5 feet), equivalent to the maximum vertical scarp in the
> San Fernando earthquake, then there were 140 earthquake events.
> If it is further assumed that most of the alluvial fans along the
> south front of the San Gabriel Mountains were formed at the end
> of the Pleistocene, when the climate must have been much more
> humid, then each earthquake recurrence was about 70 years
> (10,000/140). Unfortunately, the age of the fans have not been
> dated, so if they were formed 20,000 years ago the recurrence
> would be 212 years. Using the 30,000-year-old fan age, and a
> displacement of 150 cm, the slip rate is 0.75 cm/yr. This is
> the same as derived for the San Fernando fault based on a 200-
> year-old recurrence interval suggested by age-dated wood (see
> following discussion).

The writer questions some of the assumptions made in the above calculation,

especially the age of the alluvium.

B. Sawpit Canyon fault zone

This fault zone is shown on figures 3b, 3c, and 3d. It is compiled from the maps of Dibblee (1958) and Morton (1973). It appears that they are the only workers who have done original mapping of the fault zone. Morton's (1973) mapping is the more detailed, but includes only the southwestern 5.5 km of the zone. He refers to the fault zone as the Sawpit-Clamshell fault zone, a 1 km-wide zone of sub-parallel faults that extend up both Sawpit and Clamshell Canyons.

The Sawpit Canyon fault zone has a general east-northeast trend. At the northeastern end, Dibblee (1950) shows it curving eastward into the canyon of the east fork of the San Gabriel River. At the southwestern end, Morton (1973) shows the fault zone curving westward and ending at Santa Anita Canyon where it is covered by alluvial deposits. The western end of the Sawpit-Clamshell fault zone would appear, however, to be the eastward continuation of the Sierra Madre fault zone, as shown to the west of Santa Anita Wash on Morton's map. He states (p. 18), "... my preferred interpretation is that the Clamshell-Sawpit fault zone becomes the frontal fault zone to the west of Santa Anita Canyon, and is masked by alluvium of the San Gabriel Valley."

Dibblee (1958) shows a northeasterly dip on the fault. Morton (1973) shows northerly to northeasterly dips ranging from 35° to 70° on the various branches of the fault. The sense of movement has apparently been thrust or reverse; Morton (1973, p. 17) mentions the basement being thrust over alluvium in at least one exposure (near the mouth of Santa Anita Canyon). Also, the topography rises much more abruptly, and to much higher elevation, on the northwestern side of the fault than to the southeast. There may also have been a significant component of lateral movement along

the zone, but both Dibblee (1958) and Morton (1973) show a similar

suite of basement rock units in the terrane on both sides of the fault,

suggesting that there has not been a great amount of lateral movement.

Morton (1973, p. 19) suggests that about 4,000 feet of vertical displace-

ment has occurred along the Clamshell-Sawpit fault zone, northeastern side

up.

Morton (1973, p. 17) describes the northernmost fault of the

zone as having a crushed and sheared zone as much as 300 feet thick.

He mentions that the southernmost fault of the zone has a crushed and

sheared zone about 20 feet thick.

Regarding recency of movement, Dibblee (1958) shows the fault

as the contact between crystalline basement rock and older alluvium in

several places. He does not show the fault bounding or cutting any

younger units. Morton (1973) shows the faults within the Sawpit-Clamshell

fault zone as cutting only crystalline basement rock, except for the

above-mentioned fault near the mouth of Sawpit Canyon. He states (p. 20),

"In the mapped area, the youngest documented fault displacement is post-

San Dimas Formation and post-older stream deposits (Qao_1) and pre-younger

alluvium (Qal)..." Morton (personal communication, 10-7-77) also said

that he knew of no scarps or other geomorphic features along this fault

zone that he considered to be as young as Holocene age. Miller (1928,

p. 206) describes a very youthful scarp along the "Sawpit fault", but

it turns out that the scarp, near the town of Arcadia, is along what is

now called the Raymond Hill fault.

C. Frontal fault zone, central part

This part of the range front extends from Santa Anita Canyon

on the east to about Las Flores Canyon on the west (figure 3d). On

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the east, the range-front fault zone appears to be the westward continuation of the Sawpit Canyon fault. Morton (1973, p. 18) expresses a similar view. On the west, the range-front fault zone converges with (or continues as) the south branch of the San Gabriel fault.

This part of the range front fault system is similar in most respects to the eastern part. It is characterized by numerous sub-parallel faults, some of which are well defined, but most of which are poorly defined. There is some landsliding along most of the front. In the Henninger Flats area, Saul (1976) shows widespread landsliding on a major scale.

Only two workers have done useful mapping in this area: Morton (1973) did the eastern half of the Mt. Wilson quadrangle, and Saul (1976) did the western half, both at a scale of 1:12,000. Most of the faults shown on their maps cut only the pre-Tertiary crystalline basement rock. Locally, the basement rock, on the north, is thrust over older alluvium or the middle Pleistocene San Dimas Formation to the south. Saul infers some faults beneath the alluvium, just beyond the base of the lowest hills along the front. Neither Morton or Saul show any faults of the "ground-water barrier" type. Both Morton and Saul show short occurrences of faulted Holocene alluvium in several places, but these are apparently drafting errors (Morton even shows faulted artificial fill in one place!); both Morton (personal communication, 10-7-77) and Saul (personal communication, 1977) said they knew of no specific evidence for Holocene faulting in this area.

The mapped fault-plane attitudes in this area show most of the faults to be north or northeast dipping. Dip values covering the complete range between 30° and 70° predominate. The mountain front rises very abruptly in this area, and that, coupled with the numerous occurrences of bedrock on the north thrust over alluvial strata to the south, indicates that the predominant sense of movement has been thrust or reverse with the northern side upthrown. None of the workers give a value for the total uplift of this part of the range front, but the topography suggests that between 1000 m and 1500 m of vertical displacement occurred during Quaternary time.

Payne and Wilson (1973, p. 2) state, "Along the Raymond fault and portions of the Sierra Madre and Cucamonga faults, Recent and Quaternary alluvial deposits have been displaced against recent alluvium, suggesting tectonic movement in the Holocene." They do not, however, anywhere in their report indicate that such features occur along this part of the Sierra Madre fault. D.P. Smith (work in progress) did detailed mapping along the range front eastward to about 0.5 km east of Las Flores Canyon, and observed no evidence of Holocene faulting. The writer also inspected trenches at Eaton Wash Dam (12-8-77) and observed no evidence of faulting. These trenches, shown on figure 3d, were excavated by the Los Angeles County Flood Control District to determine if a recently active fault extended down the northeast side of Eaton Wash and passed beneath the dam. The trenches were not deep enough (10 feet maximum depth) to determine if an older fault, that does not cut the younger, upper alluvium, passes beneath the dam. Nor did the trenches extend far enough to the northeast to determine if a fault,

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recently active or otherwise, extends along the base of the hills beneath
New York Drive.

Saul (1976) mapped a number of faults to the north of the Sierra
Madre fault zone, including faults or shear zones in Bear Canyon and
Grand Canyon. These are compiled on figure 3d. Saul states (p. 13),
"No data were found during the present study relating to the recency of
movement on faults within the range north of the Sierra Madre fault zone."
He further suggests that some of those faults may be pre-Tertiary in age.

Some of the faults of Envicom Corporation (1975) are compiled
on figure 3d of this FER, mainly as a matter of record -- Envicom,
unfortunately, does not state the basis on which the existence or
location of these faults was established.

D. South Branch of the San Gabriel fault

This fault diverges from the north branch of the San Gabriel
fault in Big Tujunga Canyon (figure 3f), extends southeasterly across
the San Gabriel Mountain front, eventually swinging in along the range
front at about Las Flores Canyon (figure 3e). To the east of Las Flores
Canyon, this fault is known as the Sierra Madre fault zone. To the west
of Las Flores Canyon, the south branch of the San Gabriel fault is the
major structural and lithologic boundary; there apparently is no through-
running "Sierra Madre fault zone" extending westward along the range
front between Las Flores Canyon and Angeles Crest Highway. Miller (1934)
shows many basement rock units common to both sides of the south branch
of the San Gabriel fault, but, while making a detailed map of the north
half of the Pasadena quadrangle (Smith, 1977a), the writer found no
basement rock units common to both sides of that fault. This suggests
that major lateral displacement has occurred along the south branch of

the San Gabriel fault (and possibly also along the central part of the
Sierra Madre fault) since Cretaceous time.

This fault is generally fairly well defined. Although the
zone of gouge and sheared rock is at places as much as 300 m wide, it is

basically a "one fault" zone. This is in contrast to the central and eastern parts of the Sierra Madre fault zone, where numerous sub-parallel faults occur along a zone that is 1 km or more in width. The south branch is characterized either by basement rock thrust over alluvial strata, or by basement rock against basement rock. In the latter case, the fault is locally accompanied by a clay gouge zone as much as 40 m thick. The locations of two excellent exposures of this feature are shown on figure 3e. Where Angeles Crest Highway crosses the fault (figure 3f), the fault is exposed in cuts on both sides of the highway. Basement rock on the northeast is thrust over older alluvium on the southwest. The older alluvium lies depositionally on lower plate basement rock. All of this can be observed in this roadcut. Figure 3e shows the locations of several other places where the basement rock is thrust over older alluvium. In the area of Big Tujunga Canyon the south branch was observed by the writer to cut only basement rock. Shearing and crushing is extensive along a zone as much as 100 m wide, but clay gouge zones are discontinuous and generally do not exceed one meter in thickness. Topographically, the only local expression of the fault is in the form of differential erosion -- some drainages follow the more easily eroded fault gouge.

There is an obvious discrepancy between the location of the south branch of the San Gabriel fault as shown by the writer and that shown by Ehlig (1967). The writer's location of the fault within the Pasadena quadrangle is based on detailed field mapping. Within the Condor Peak quadrangle, the portion of the fault at, and southeast of, Angeles Crest Highway was mapped in detail, but the remainder of the

fault was mapped   on the ground by what would have to be

called reconnaissance mapping. The writer, however, had the benefit,

because of his work on the Pasadena quadrangle, of being able to readily

recognize the basement rock lithologies characteristic of each side of

the fault. This allowed the writer to quickly locate the principal

"contact fault", and, where the fault passes beneath the alluvium of

Big Tujunga Creek, to know with certainty that the fault was in fact

there because of the contrasting basement rock lithologies on opposite

sides of the canyon bottom. Ehlig (1967) shows the south branch extending

up Vasquez Creek (at the southeasternmost extreme of Big Tujunga Canyon).

The writer did observe a fault extending up that small drainage, but it

dies out about one kilometer from the mouth. That fault, however, is

well exposed in a cut bank of Big Tujunga Creek by the mouth of Vasquez

Creek, and that may be the reason that Dibblee and other earlier workers

presumed it to be the main fault (R.J. Proctor, personal communication,

1976, said he also had seen this fault and presumed it was the main trace

of the south branch).

There is significant variation in the attitude and apparent

sense of displacement along different parts of the south branch. Along

Big Tujunga Canyon, the fault is vertical or dips as much as 70° to the

southwest. The sense of movement appears to have been reverse, south-

western side upthrown. The very oversteepened northeastern side of Mt.

Lukens suggests at least a few hundred meters of uplift along the south

branch during late Pleistocene time. Between Big Tujunga Canyon and

Angeles Crest Highway the fault attitude changes from high angle to about

a 45° northeasterly dip. Along this segment of the fault, the sense of

offset is not apparent. From Angeles Crest Highway to about one km west

of the eastern boundary of the Pasadena quadrangle, the dip of the
fault generally does not vary more than 10° from 45° NE. Along this
segment of the fault, the occurrence of basement rock thrust over alluvial
strata indicates thrust or reverse movement, northeastern side upthrown.
Also, to the southwest of the fault the terrane is at relatively low
elevation, but, to the northeast, Brown Mountain rises very steeply.
This last observation suggests a vertical component of offset, during
Pleistocene time, of at least 500 m along this segment of the fault.
Farther to the southeast, between Chiquita Canyon and Las Flores Canyon,
the fault curves over, that is, the fault plane curves over into much
lower angles, and, locally, actually shows a contact fault plane dipping
shallowly to the southwest. The sense of movement was obviously thrust,
northeastern side upthrown.

The writer observed no evidence of Holocene activity along the
south branch of the San Gabriel fault. No other workers in this region
present evidence or make any statements about the recency of activity
along this specific fault. Where the writer has observed basement rock
thrust over alluvium along this fault, the alluvium is, without doubt,
very much older than 11,000 years. In at least five places, late
Pleistocene alluvium overlying the fault is not cut by the fault.

E. Frontal fault zone, western part

There are only two useful sources of mapping along this part
of the range front. The part of the range front within the Pasadena
quadrangle was mapped in detail by Smith (1977a). All of the range front
between Big Tujunga Canyon and San Gabriel Canyon has been mapped at a
reconnaissance level, with some local detailed work, by Payne and Proctor
(1977). Their mapping is used, in this report, only for that part of

the range front that lies between the western boundary of the Pasadena quadrangle and Big Tujunga Canyon. In the discussion that follows, the faults will be described on an east-to-west basis.

This part of the range front extends from Las Flores Canyon on the east to Big Tujunga Canyon on the west. From Las Flores Canyon to about one kilometer west of that canyon, the principal range-front fault is the southeastern end of the south branch of the San Gabriel fault (already discussed). Between there and about Angeles Crest Highway, the range front is topographically poorly defined. This part of the range front is herein referred to as the Arroyo Seco area. Small to moderate amounts of uplift have occurred in this area along a series of west- and northwest-trending reverse faults that occur in imbricate fashion between the front of Gould Mesa (the JPL area) on the southwest and the south branch of the San Gabriel fault on the northeast. From Angeles Crest Highway westward to Haines Canyon, the Mt. Lukens thrust fault is the fault along which most of the uplift of that part of the range front has occurred. Some of the uplift along that part of the range front has also occurred along the Falls Canyon fault, a west-northwest-trending high-angle fault that lies about one km northeast of the Mt. Lukens thrust fault. To the west of Haines Canyon, the range front again becomes poorly defined. As in the Arroyo Seco area, uplift has apparently occurred on a series of west- to northwest-trending reverse or thrust faults.

Several other unusual fault-like features are included in this discussion. These features, which occur on the crest and south flank of Mt. Lukens, are similar to "gravity faults" caused by "lateral spreading" or "gravitational spreading" as described by Beck (1968) and Radbruch-Hall and others (1977).

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There are six significant mapped faults in the Arroyo Seco area, including such named faults (Smith, 1977a) as the JPL fault (also called "Bridge fault"), the Swimming Pool fault, and the La Vina fault. These faults are all north to northeast dipping, with considerable local variation in dip angle. Generally, however, the angle ranges between 30° and 60°. In all cases the movement has been reverse or thrust, northern side upthrown.

The JPL fault is the southern structural boundary of Gould Mesa. This fault is well exposed along a road on the east side of the mouth of Arroyo Seco Canyon (just east of the JPL bridge across the Arroyo Seco).

There, the fault dips 40° N with granitic basement rock thrust over older alluvium. The Jet Propulsion Laboratory has done extensive exploratory drilling and some trenching on their grounds (to the west of the mouth of Arroyo Seco) during the past two years, and have exposed the fault or intersected the fault plane of the JPL fault in many places (this information from R. Proctor and R. Crook, personal communication, 1977). These drill holes and trenches also showed the fault to dip about 40° N, with basement rock thrust over older alluvium or Pacoima Formation (middle-late Pleistocene) strata. Two of the deeper drill holes showed the granitic basement to be about 250 m below the surface immediately to the south of the JPL fault. Immediately to the north of the fault, the granitic basement rock extends about 60 m up the face of Gould Mesa, indicating somewhat more than 300 m of vertical separation on the JPL fault.

Payne and Wilson (1973, p. 3) state that Converse, Davis and Associates, in a bridge foundation investigation for the JPL bridge, observed that "Dip-slip movement of 0.8 foot was present in the most recent alluvium." R. Proctor and R. Crook (personal communication, 1977) said that the JPL trenching and drilling program uncovered no additional evidence of recent fault movement. The writer, during his detailed study of the north half of the Pasadena quadrangle, noted that, on older aerial photo sets, there were no scarps cutting the two prominent terrace surfaces that overlie the eastward projection of the JPL fault immediately east of Arroyo Seco Canyon. At the time the oldest photos were taken (1933), those two terrace surfaces were in nearly pristine condition (they were urbanized after World War II). The lower of these

two terraces lies about 40 m above the present stream channel, and, presumably, is older than Holocene. Farther to the east, between Lincoln Avenue and Las Flores Canyon, there is no evidence, not even gross topographic evidence, for the existence of the fault; it may simply die out in that direction. In the exposure of the fault in the east wall of Arroyo Seco Canyon (to the east of the bridge), the fault appears to die out upward within older alluvium. This exposure has been very well cleaned off and dug out by many workers during the past several years, but even so, the fault can be seen to extend up the canyon wall to no closer than about 15 m below the lower of the two previously mentioned terrace surfaces. It is possible, however, that in the poorly consolidated older alluvium the expression of the fault simply cannot be seen.

The westward continuation of the JPL fault is uncertain. The gross geomorphology of Gould Mesa indicates that there must be a significant bounding fault along the southwestern side of the mesa between the JPL grounds and Angeles Crest Highway. The writer noted some faint photo lineaments in this area on 1933 photography. These are mapped (Smith, 1977a) as queried dashed faults. Because of thorough urbanization on this area, nothing could be seen on the ground.

The Swimming Pool fault is an east-west trending fault that crosses Arroyo Seco Canyon about 300 m. north of the JPL fault. A good exposure near the mouth of Millard Canyon shows the fault dipping 65° N. This fault does not cut the lower of the two terraces on the eastern side of the canyon, but it exhibits a modified but well-defined 4 m-high scarp across the upper terrace surface. The writer believes this surface is very much older than 11,000 years. The scarp may at one time have continued farther to the east, but the terrace surface has been

either eroded or buried in that direction. The total vertical offset
on this fault may be less than 10 m.

An unnamed east-west-trending fault crosses Arroyo Seco Canyon
about one km up the canyon from the JPL fault (near the mouth of El
Prieto Canyon). Two good exposures show granitic basement rock thrust
over Pacoima Formation strata (middle-late Pleistocene). To the east of
El Prieto Canyon, older aerial photography (Fairchild, 1933) shows no
scarps on either of the two prominent terrace surfaces that overlie the
eastward projection of the fault. These surfaces are lateral equivalents
of the same terrace surfaces previously discussed. To the west, the
fault does out within Pacoima Formation beds that underlie Gould Mesa.
At the top of the mesa, the generally flat-lying Pacoima Formation beds
show a strong monoclinal warp over the westward projection of the fault --
with south dips as steep as 33° . The total vertical offset on this fault
is at least 50 m, but nore than half of that occurred before or during
deposition of the Pacoima Formation. The monoclinal folding in the
upper part of the Paicoma section has, of course, resulted from fault
movement subsequent to the cessation of Pacoima deposition in this area.
Because the expression of this faulting is in the form of monoclinal
development, there is no apparent way to determine the recency of the
movement. However, to the east this fault passes beneath younger terrace
surfaces (discussed above) that it appears to not cut or deform. Thus,
it is not likely that there has been Holocene displacement along this
fault.

The La Vina fault is a west-northwest-trending fault with
highly variable dip that passes just north of the La Vina Hospital and

samitorium. Granitic basement rock is thrust over Saugus Formation
strata on the ridge between Fern and El Prieto Canyons. In El Prieto
Canyon, at least 45 m of Pacoima Formation strata have been overthrust
by basement rock along this fault. The upper of the two terrace surfaces
to the east of El Prieto Canyon shows a very modified scarp, one to two
meters high, on older aerial photography. The lower of the two terrace
surfaces is absent at the point where the fault crosses El Prieto Canyon,
so it cannot be said with certainty that that surface was not cut by the
faults. Parts of the lower terrace do continue upstream from the fault,

however, and these appear to be on a continuous grade with their downstream equivalents. Thus, it is probable that the last vertical movement on this fault predated the abandonment of the lower terrace surface. For a distance of about one km along the fault, in the vicinity of La Vina hospital, basement rock is thrust over Saugus Formation strata. The amount of vertical offset there is unknown. Smith (1977a) infers this fault to extend eastward to the south branch of the San Gabriel fault, on the basis of a gross topographic trend. At the western end, the writer could not follow the fault beyond Fern Canyon.

Another west-northwest-trending fault, unnamed, lies about 600 m northeast of the La Vina fault. This fault cuts only basement rock, except on two high ridges between Fern and El Prieto Canyons where basement rock is thrust over remnants of a former covering of Pacoima Formation strata. To the west the fault could not be followed beyond Fern Canyon. To the east the fault passes beneath a Holocene landslide on the oversteepened northwest wall of Millard Canyon. Farther east, the fault continues to the south branch of the San Gabriel fault, but it is mapped only as a broad shear zone (not shown on figure 3e) because no single, well-defined, continuous faults could be followed.

A very shallow-dipping, unnamed thrust fault occurs in the west-central part of the Gould Mesa area (labeled "Golf Course fault on figure 3e). This fault was observed only on the grounds of the La Canada Country Club golf course. It manifests itself only as a gouge and crushed zone within granitic basement rock. The gross topography of the area (a steeply rising slope to the north of the fault) reflects the probable northeast-side-upthrown character of the fault, but there

is no geomorphic evidence along the fault indicative of recent movement.

This completes the description of the faults in the Arroyo Seco area. In summary, the writer found no evidence of Holocene displacement in this area. The 0.8 foot offset of recent gravel ascribed to the JPL fault by Converse, Davis and Associates is the only evidence presented by any worker for Holocene faulting in the Arroyo Seco area.

The Mt. Lukens thrust fault is the principal range-front fault between Angeles Crest Highway and Haines Canyon. The fault can actually be followed eastward down across the bottom of Arroyo Seco Canyon, but it apparently dies out within one km east of the canyon. Only about 30 percent of this fault is exposed along the range front between Angeles Crest Highway and Haines Canyon. The balance is buried by Holocene and late Pleistocene alluvium. The fault is a north-dipping thrust fault, north side upthrown. Attitudes along the fault range from about 30° N to 10° S. The south dips occur only in the area between Gould Canyon and Pickens Canyon. A thrust fault has to curve over to attain reverse dips such as these. The writer proposes a mechanism for this fault geometry along this fault. If the average rate of advance of the upper plate of a thrust fault is too fast, erosion cannot remove the leading edge of the plate as rapidly as it advances. In this case, the leading edge will collapse, or "slop over", and be pushed, by the advancing mass of the upper plate behind it, out across the natural surface of the lower plate. Where the thrust fault is located at the base of a range front, as was apparently the case here, the upper plate is then pushed down over the existing alluvial fan or pediment surface, thus giving rise to the reverse fault dip. C.M. Marshall, in a talk given at a South Coast Geological Society meeting in Tustin

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(September(?) 1977) presented a similar description of the nature of the thrust faulting along this part of the range front. He used the term "flops over". The writer chooses not to use that term because "flop" suggests overturning, and it is not apparent that anything has overturned in this case.

In the vicinity of Gould Canyon, the repitition of the thrust fault is caused by a south-dipping normal fault that downdropped the entire "front" part of the thrust fault nearly 100 m.

Most exposures of the Mt. Lukens thrust fault show basement rock thrust over alluvial strata. East of Dunsmore Canyon (figure 3e), these alluvial strata range in age from late Pleistocene (the oldest member of the "older fanglomerate series" of Smith, 1977a), to Plio-Pleistocene (Saugus Formation). At and west of Dunsmore Canyon (figure 3g), alluvium probably as young as Holocene age is overthrust by basement rock. The above statement is based on a reconnaissance study of the area by the writer; the map of Payne and Proctor (1977) does not show that relationship. However, two youthful-appearing scarps cross the probable Holocene age alluvium at the mouth of Dunsmore Canyon, and the more northerly of these is shown on the map of Payne and Proctor. It is the only indication of Holocene faulting on their map. The writer has observed the more southerly of the two scarps, both on photos, and on the ground; but this feature and other features suggestive of Holocene faulting to the west of Dunsmore Canyon have not yet been mapped by the writer.

It is the opinion of the writer, based on his own work, that there are no features indicative of Holocene activity along the Mt. Lukens thrust fault to the east of Dunsmore Canyon. Between the east side of the mouth of Dunsmore Canyon and the mouth of Blanchard Canyon

there definitely are features suggestive of Holocene faulting (figure 3g).
Such features may also exist to the west of Blanchard Canyon, between
there and Big Tujunga Wash, but there is no indication of Holocene faulting
in that area based on the available literature.

There are several faults that lie as much as one km to the north
of the Mt. Lukens thrust fault. The longest of these, the Falls Canyon
fault, is a high-angle fault that trends parallel to the range front.
This fault is very likely related to the Mt. Lukens thrust fault in some
way; certainly it intersects or is truncated by the thrust fault at depth.
The writer observed this fault to cut only basement rock along its entire
length; no evidence for Holocene activity was seen. In the Briggs Terrace
area (just west of Pickens Canyon, figure 3e), two older scarps can be
seen, on Fairchild (1931) aerial photography, cutting the highest terrace
surface. These are shown as dashed faults on the map of Smith (1977a).
The uppermost scarp is very modified and no more than 2 m high. The
lower scarp is well defined, although not sharp or fresh appearing, and
is about 15 m high. Both of these faults cut a surface that the writer
believes to be very much older than Holocene. The lower scarp has been
washed out at the eastern end (immediately west of Pickens ravine). That
surface, now a terrace about 20 m above the modern channel, is not cut
by the fault. The writer believes that terrace surface to also be pre-
Holocene in age. To the east and west of Briggs Terrace, faults were
mapped in bedrock (Smith, 1977a) that may be the same as the faults that
formed the scarps. These are north-dipping thrust faults. The bedrock
exposures of these faults showed no evidence of Holocene activity.

To the west of Haines Canyon, between there and the mouth of
Big Tujunga Canyon (figure 3g), the only geologic descriptions are
embodied in the annotated map of Payne and Proctor (1977). Their map
shows several inferred and dashed faults trending westward toward Big
Tujunga Wash. Along their southernmost fault, where it crosses the fans
of Rolley and Zachau Canyons, they apparently observed features that are
indicative of recent, possibly Holocene, faulting. They show the fault
cutting relatively young alluvium (but not the most recent alluvium) in
the vicinity of the 30° dip symbol at the wash coming out of Rowley
Canyon. To the east and west of that location, on the same fault, they
have annotations on their map about scarps and lineaments observed on
1928 aerial photography.

The last faults to be discussed are the "lateral spreading"
type features that occur along the crest and south side of Mt. Lukens.
These features occur in the southwest corner of the Condor Peak quad-
rangle, to the southwest of the south branch of the San Gabriel fault.
Some of the features just west of Pickens Canyon also extend south into
the Pasadena quadrangle for a short distance. All of these features are
characterized by "back-facing" scarps in basement rock. That is, the
scarps appear to be generated by faults that dip into the slope, and,
in every case, the upslope side of the scarp is downthrown, generating
scarps that face back up the slope. Where the faults occur along
opposite sides of the ridgecrest, the back-facing scarps face each other
across the ridge. The occurrence of features of this type in New Zealand
is described by Beck (1968).

The varying appearance of these scarps suggests a wide range of ages. One of the scarps on the south side of the ridgecrest, near the head of Pickens Canyon, appears to be accompanied by a closed depression -- when viewed on Fairchild (1933) stereo aerial photography. On-the-ground examination by the writer in 1977 revealed that the damming scarp has now been breached, and the depression is no longer closed (this site is marked "ponded alluvium" on figure 3f). This scarp, along with some of the other more youthful-appearing scarps along the ridgecrest, may have been generated during Holocene time. To the south side of the ridgecrest, the high ridge spur between Pickens and Shields Canyons is also bracketed by a pair of prominent back-facing scarps. These two scarps converge at the southern nose of the higher part of the spur, forming a "V" shaped pattern in map view. The more easterly of the two scarps, which trends down the western side of Pickens Canyon, has a very strong, youthful appearance. At least one fair-sized closed depression still exists along this fault (location shown on figure 3f). The writer has visited this feature on the ground. The fault scarp crosses a very steep slope. That slope, like most steep slopes along the range front, is undergoing relatively rapid erosion. The closed depression appears to be filling rapidly. At other places along this fault, there are areas that may also have been closed drainages, but they are now filled with debris from the slope. It is the writer's impression that closed depressions of the sizes that exist (or existed) here would be filled in no more than a few hundred years. It appears almost certain that normal faulting, with a vertical offset of 2 m to 5 m has occurred here during the past 1,000 years.

Seismicity

There is no mention in the literature of an earthquake being uniquely associated with any of the faults considered in this report. The seismicity maps (figures 2a and 2b) do not show any significant epicenter patterns associated with these faults.

6. ## Interpretation of aerial photography

    None.

7. ## Field observations

    None.

8. ## Conclusions:

    West of the western boundary of the Pasadena quadrangle, at least part of the Mt. Lukens thrust fault meets our criteria for being sufficiently active and well defined. However, the quality of the existing mapping in this area is not sufficient to allow the establishment of the boundaries of a special studies zone(s). East of the western boundary of the Pasadena quadrangle, none of the faults considered in this report (excepting the lateral-spreading type "faults" in the Condor

Peak quadrangle) meet our criteria for being sufficiently active.

Many of the faults, especially those in the Mt. Baldy, Glendora, and

Azusa quadrangles, probably do not meet our criteria for being sufficiently

well-defined. The lateral-spreading type faults on Mt. Lukens, meet our ^{where mapped,}

criteria for being sufficiently active and well defined. But, for

Fault Evaluation Program purposes, should these features be defined as

faults?

9. Recommendations

I recommend that at least the first kilometer of the Mt. Lukens

thrust fault to the west of the western boundary of the Pasadena

quadrangle be zoned. But, additional mapping in that area will first

have to be completed to determine the extent of the fault to be zoned.

Depending on our findings in that area, zoning may be required westward

all the way to Big Tujunga Wash. I recommend that none of the other

faults considered in this report (except the lateral-spreading type

faults) be zoned. I have no recommendation regarding the lateral-

spreading type faults on Mt. Lukens. If, however, it is decided that

these should be zoned, a small amount of additional field work will be

required to decide which of the mapped features should be zoned and how

wide the zones should be (probably very narrow).

10. Investigating geologist's name and date:

DREW P. SMITH
Geologist
January 19, 1978

[Handwritten annotations:]

Drew

1. I concur with your recommendations to consider zoning the Mt. Lukens fault W. of Dunsmore Cyn -- but only after more field work to be certain it meets our zoning criteria.

2. I would like to see the late Quat. fault features along the Mt. Lukens, Sierra Madre, JPL and other frontal faults before making a final recommendation.

3. I'm inclined to recommend against zoning the "lateral-spreading faults" because they: a) lie in a remote area, b) may be part of a poorly-defined "system" of ground failures (you may have mapped only a portion of the "faults") as indicated by their scatter and discontinuous pattern, and c) may be non-tectonic, and perhaps being due largely to a "type of incipient sliding and spreading of the ridges. — caused by seismic shaking and movement. If the latter is the case, then we better find the causative fault (Mt. Lukens?) which caused the E/Q's.
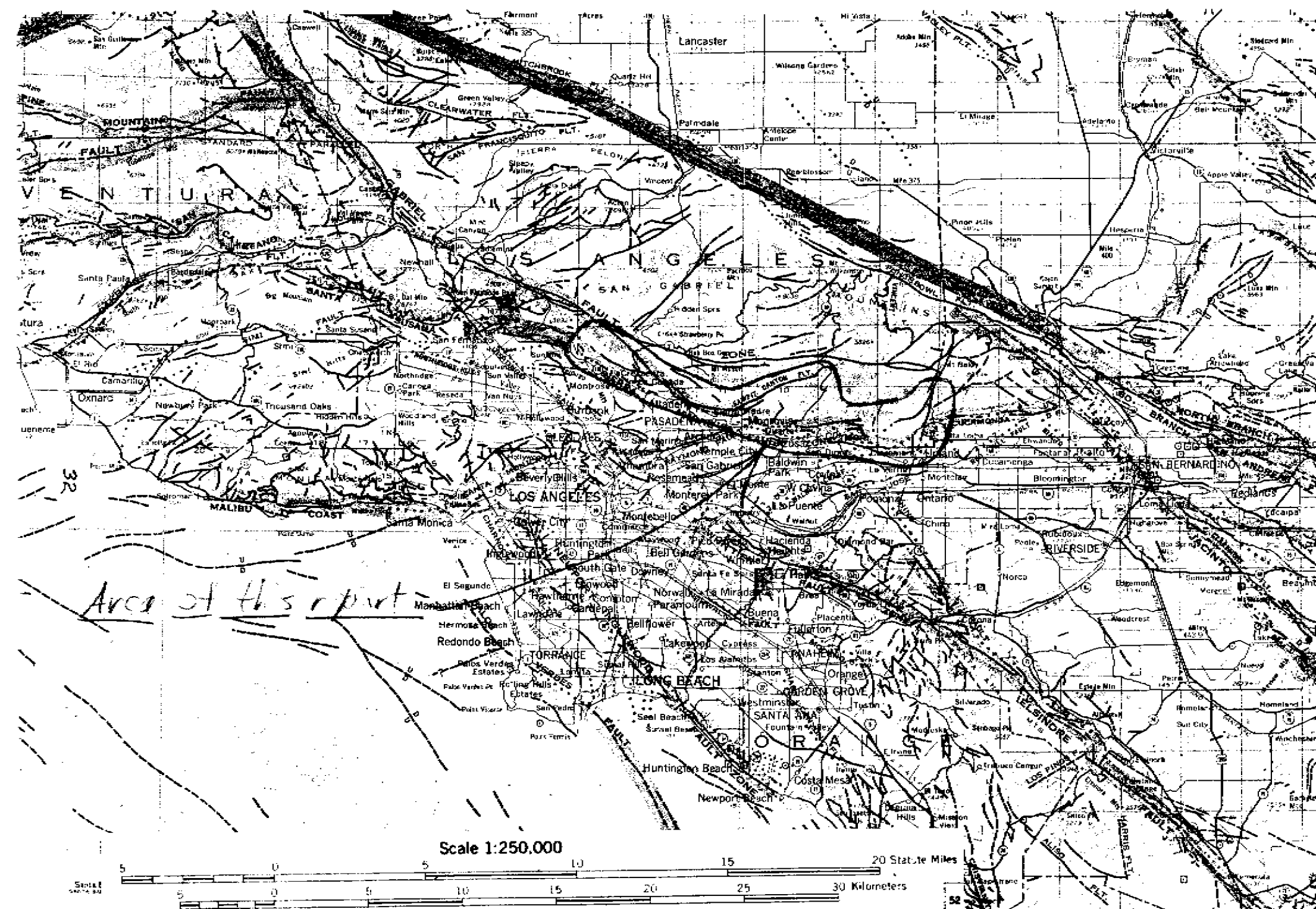
[signature] E.W.H. 2/18/78

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Figure 1. Index map showing the locations of the faults considered in this report. Modified from Jennings (1975).

Scale 1:250,000

Area of this report

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